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EFFECT OF UV- RADIATION ON FATIGUE BEHAVIOUR OF NATURAL COMPOSITE MATERIALS

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ABSTRACT

The UV-radiation effect on fatigue behaviour of natural composite materials was investigated experimentally. The egg shell - polyester, date nuclei - polyester, and palms leaf - polyester were used in this experiment using (20 %, 40%, and 60%) volume fraction. The samples were affected on UV- radiation for three different times (100 hour, 300 hour, and 500 hour). The mechanical properties of natural composite samples (with and without UV-radiation) were found. The fatigue test for natural composite samples was done. The resultant shows that, the increasing volume fraction causes increasing of endurance stress of natural composite materials. The palm leaf – polyester samples have mechanical properties better than egg shell – polyester and date nuclei – polyester samples. The increasing time of UV- radiation causes reduction in endurance and tensile stresses. The greatest and smallest reduction in stress endurance due to UV- radiation occurs in palm leaf and nuclei natural samples. The date nuclei natural composite material has good resistance to UV- radiation under fatigue effect.

***KEYWORDS:** Fatigue, Natural Materials, UV- Radiation Egg Shell, Date Nuclei & Palm Leaf*

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Original Article

INTRODUCTION

Natural material reinforced plastics have been focused on, in the last few years. Due to the natural materials low density respectably to their strength, they have been noticed to expose reasonable mechanical properties, and thus, important candidate to replace synthetic materials [1], [2]. Furthermore, its availability in nature leads to consider it as renewable raw material source that reduces cost and energy production. These materials are widely available in our society. For example, egg shell is widely available because of our usage as our food. Due to the availability of palm trees in Arabian countries, nuclei dates and Palm leaf are widely available, thus these materials are preferable to be used to reinforce polymers [3], [4]. However, polymer composites have a drawback, the adhesion between reinforcing materials and polymer. Improving the interface adhesion results in more compact material and improving mechanical properties. Nevertheless, the interface adhesion between reinforcing materials and polymer is affected by the applied stress type and environmental conditions. Such affecting stress is fatigue stress, that happens when the materials is subjected to a varying stress over a period of time. This cause either micro structure cracks at the stress concentration places or surface cracks to propagate causing adhesion degradation and cause a failure in the material [5], [6]. Also, environmental conditions such as moisture, chemical raining and ultraviolet are conditions degrade the composites mechanical properties by adhesion loosing [7]. Many researchers have paid attention in studying properties of natural material- polymer composites. Weather conditions effect on material is studied [8]. The study showed a high mechanical and hardness

characteristic when using thermoplastic reinforced with palm fibers as opposed to the fiber glass. The palm fiber content and the environmental conditions were studied and investigated. Reasonable mechanical properties but poor durability when subjected to weather conditions was concluded. Another fiber glass and palm fiber comparison was conducted in [9], both the date palm fibers and fiber glass as a reinforcing materials were used separately with a high-density polyethylene. It was found higher mechanical properties of the date palm composites than the fiber glass. A higher fiber-polyethylene adhesion was exhibited by the natural fiber though no chemical treatment was used to increase the adhesion. For certain limit of fiber content, it was found that increasing natural fiber volume fraction improves strength.

The study in [10] used micro mechanical theory is applied on the experimental accelerating weathering test, which results in the pure resin to predict the glass-resin properties. Based on the theory, the UV-radiation effect on the fiber glass-resin composite was calculated. Then, both tensile strength, and shear resistance were experimentally studied for the composite at different UV-exposure time, results indicated more properties degradation is caused by longer exposure time. The fatigue life for epoxy reinforced with E- glass fiber composites was studied in [11]. The multi layers of fibers-epoxy composites was noticed to show degradation in fatigue life after exposed to UV radiation which claimed to the brittleness caused by losing the long chain bond between the fiber and epoxy which leads the micro structure surface crack to propagate through the layers reducing the expected material failure stress. Weathering effect on the palm fiber/ Propylene was studied [12]. The composite showed little strength degradation after UV exposure as opposed to significant strength drop of the pure propylene which lost half of its strength after the same exposure time. However, in [13], the Propylene strength was studied after UV exposure both in pure form and reinforced with sisal fibers. Results showed that the strength improvements exhibited by the sisal/ Propylene composites under the same amount of UV radiation. Moreover, as the fiber volume fraction increases, there are fewer drops in the irradiated material strength.

In this work a new composite consists of natural materials that consider as cheap materials also considered as trashed materials was investigation and the UV- radiation effect on fatigue test for natural composite materials are investigated experimentally.

EXPERIMENTAL WORK

Natural Fiber Preparation

Three types of natural reinforcements to make the composite materials were used in this experiment, which are egg shell, nuclei dates, and palm leaf as shown in the figure (1). Firstly, clean the natural fibers with distilled water. By sun light, the cleaned natural fiber is dried. Then by chemical process, the cleaned and dried natural fibers are cleaned again using sodium hydroxide (80%) mixed with distilled water (20%) and the natural fibers are placed in the diluted solution. It is again dried in the sun light. After drying the natural fibers are made as a micro powder by using a mixer, see figure (2). Natural fibers were cut and then used in the manufacture of natural composite materials. The densities of the natural reinforcements and polyester resin are used in this experiment were calculated, table (1).

Egg Shell **Date Nuclei** **Palm Leaf**

Figure 1: Natural Materials

Table 1: Density of Natural Materials

Density (kg/m^3)			
Egg Shell	**Date Nuclei**	**Palm Leaf**	**Polyester Resin**
1550	950	360	1100

Composite Materials Preparation

In this experiment, the hand lay-up technique was used to prepare the samples. This technique was the simplest and oldest way to prepare composites materials. A mold (made of glass) is used to conduct the casting process of natural composite materials in addition to a roller to ensure the regular distribution of materials in the mold.

Egg Shell Powder **Date Nuclei Powder** **Palm Leaf Powder**

Figure 2: Natural Powder Materials

The mold consists of three floor parts, removable barrier and a cover. The inner face of the mold was cleaned and smeared with wax to ensure non-adhesion the polyester resin with mold walls, see figure (3). Natural powder mixed with polyester resin (which first mixes with a hardener by 2%) according to the desired volume fraction (20%, 40% and 60%). Then the mixture is placed in the glass mold and leave the sample to dry for a period of 24 hours using room temperature until the sample is ready for use, as shown in the figure (4). After molding, the cover is used to apply pressure equally all over the sample to eliminate any air gap trapped in the sample. Composite sheets of size (20×30×0.5cm) are shown in figure (5). The natural composite sheets were cut into two type samples (fatigue test sample and tensile test samples) using CNC.

Figure 3: Polyester Resin with Hardener

Figure 4: Glass Mold

Egg Shell Sheet **Date Nuclei Sheet** **Palm Leaf Sheet**

Figure 5: Natural Composite Sheets (20×30×0.5cm)

Static Tensile Test

According to ASTM D 638 [14], the mechanical properties of the natural composite samples were measured. Three specimens of natural composite for each type were measured. The specimenswere tested with and without effect of UV radiation. This test has been performed in the department of engineering materials / Al-Mustansiriyah University. Figure (6) shows the specimens of tensile test before and after the test.

Sample Before Tensile Test **Sample after Tensile Test**

Figure 6: Tensile Test Samples

Fatigue Test

Using the fatigue device (bending- alternating HSM20 figure (7)), the fatigue test was done for natural composite materials, which was found in department of mechanical engineering at Al-Mustansiriyah University. This test was performed under three points at each level of loading. According to the manual of machine's [15], the size of the specimens was selected. See Figure (8).

Figure 7: Device of Fatigue Test

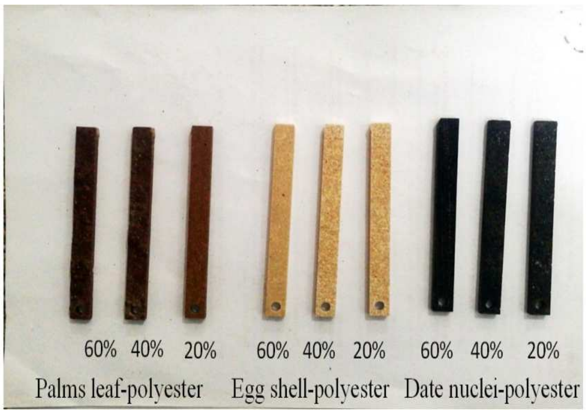

Figure 8: Samples of Fatigue Test for Natural Composite Samples at Different Volume Fraction

Accelerated UV Radiation Chamber

There are many accelerated methods to simulate ultraviolet radiation but the more popular accelerated UV techniques are fluorescent ultraviolet tube and the xenon arc lamp. The short wavelength portion of sunlight is responsible for much of the degradation of materials and fluorescent tubes simulate this portion very well which is used in this study. The prediction of environment effect on natural composite materials using natural weathering exposure is too slow. Therefore, the accelerated weathering chamber was used in the present study. The UV-radiation chambers, which are constructed for this study is shown in figure (9). Fluorescent tubes placed inside the chamber as five stages, which has (20W power) and wavelength in the range 200-280 nm as measure. The distance between each stage is (20cm), each stage contains five fluorescent tubes and controlled by a control switch.

Figure 9: UV Radiation Device Chamber

EXPERIMENTAL PROCEDURE

The study of the fatigue behavior of natural composites with or without the effect of UV- radiation involves the following procedure

- The deflection of all samples is (2mm), and the width is (8 mm). 0.95 from the ultimate stress was the first level of load. Then, gradually decrease the value by 0.1until reaches the endurance stress.
- The specimens were placed inside the UV device for three different values of times (100 hour, 300hour, and 500 hour). Then test the specimen with the fatigue machine.
- From the fatigue test, the number of cycles at a failure was recorded and (S-N) curve was plotted.

RESULT AND DISCUSSIONS

Table (2) shows the resultant of tensile test for egg shell- polyester, date Nuclei- polyester and palm leaf -polyester composite samples with three values of volume fraction (20 %, 40 %, and 60%). From the table, it can be seen that, the palm leaf- polyester composite gives higher modules of elasticity, Poisson ratio and ultimate stress compared with same properties for egg shell-polyester composite samples and date nuclei - polyester composite. The increasing volume fraction causes increasing in mechanical properties of natural composite due to increase of natural fiber which are stronger than polyester resin.

Figures (10, 11 and 12) gives the S-N curve for egg shell-polyester composite samples with different time of UV-radiation effect at (20%,40%, and 60%) volume fraction respectively. From the figures, the increasing time of UV-radiation between (100 hours to 300 hours) will not have an effect on S-N curve for egg shell natural composite materials. But, when the time of UV-radiation increases to 500 hours the time to failure will be decreasing and the effect of radiation was clear because the increasing time of radiation causes cracking the bonds between molecules. The increasing volume fraction make the natural egg shell composite samples stronger compared with small volume fraction due to increase the amount of fiber which is stronger compared with matrix. The increasing volume fraction decreases the effect of UV- radiation on the natural composite materials, which means, the polyester resin was affected on UV-radiation more than polyester resin.

Figures (13, 14 and 15) give the S-N curve for date nuclei-polyester composite samples with different time of UV-radiation effect at (20%, 40% and 60%) volume fraction respectively. From the figures, the increasing volume fraction make the date nuclei composite samples stronger when compared with small volume fraction duo to increase in the amount

of fiber which is stronger compared with matrix. The increasing time of UV-radiation will not have an effect on S-N curve for date nuclei natural composite materials. Because the date nuclei are not affected by the UV-radiation and the effect of radiation is negate when the volume fraction reaches 60 %.

Figures (16, 17 and 18) give the S-N curve for palm leaf-polyester composite samples with different time of UV-radiation effect at (20%, 40% and 60%) volume fraction respectively. From the figures, the increasing volume fraction make the palm leaf composite samples stronger compared with small volume fraction due to increase in the amount of fiber which is stronger compared with matrix. The increasing time of UV-radiation will be very effective on S-N curve for palm leaf natural composite materials. Because the palm leaf is affected by UV-radiation and the effect of radiation is clear when the volume fraction reaches 60 %.

Table (3) gives the reduction of endurance stress for natural composite material duo to UV-radiation at study, the state of S-N curve. From the table, the maximum reduction in the endurance stress occur in the palm leaf-polyester natural composite sample at (500 hour) UV-radiation and minimum reduction in the endurance stress occur in the date nuclei-polyester natural composite sample at (500 hour) UV-radiation, which means, the palm leaf is more effective by UV-radiation and date nuclei is not affected by it.

Figures (19, 20 and 21) give the tensile test result egg shell – polyester, date nuclei – polyester, and palm leaf-polyester composite samples respectively, at different time of UV-radiation effect and different volume fraction (20%, 40%, and 60%). From the figures, the increasing UV-radiation time causes decreasing ultimate stress because the UV-radiation makes the bonds weaker between the atoms. This effect decreases when the natural composite is date nuclei samples and increases for palm leaf samples.

Table 2: Mechanical Properties from Tensile Test for Natural Composite Materials Samples without UV-Radiation

Composite Samples	Volume fraction %	Modules of Elasticity (MPa)	Poisson Ratio	Ultimate Stress (MPa)
Egg Shell	20	318	0.20	23.26
	40	448	0.24	35.62
	60	563	0.27	39.59
Date Nuclei	20	300	0.17	12.52
	40	390	0.19	14.67
	60	470	0.21	15.3
Palms Leaf	20	340	0.31	32.11
	40	490	0.27	38.56
	60	633	0.41	42.83

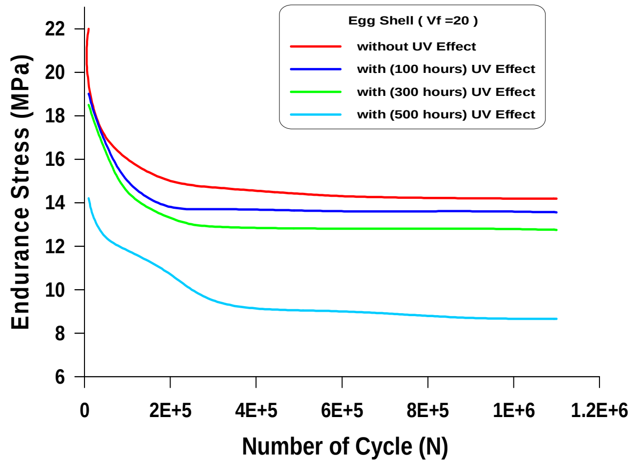

Figure 10: UV- radiation Effect on Fatigue Test for Egg-Shell Composite Materials at 20% Volume Fraction

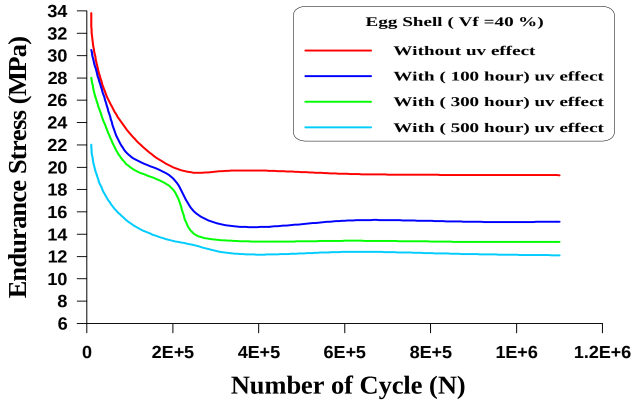

Figure 11: UV- Radiation Effect on Fatigue Test for Egg-Shell Composite Materials at 40% Volume Fraction

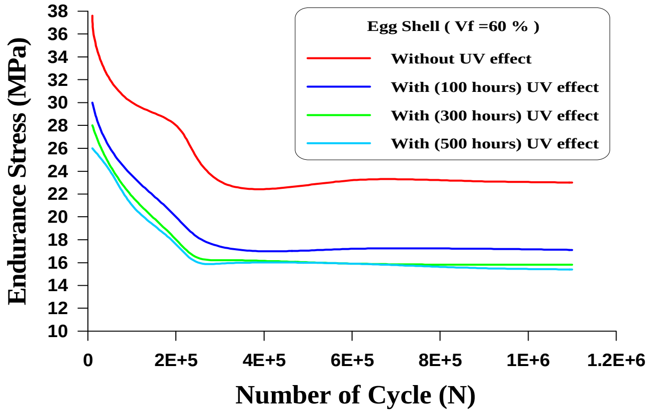

Figure 12: UV- Radiation Effect on Fatigue Test for Egg-Shell Composite Materials at 60% Volume Fraction

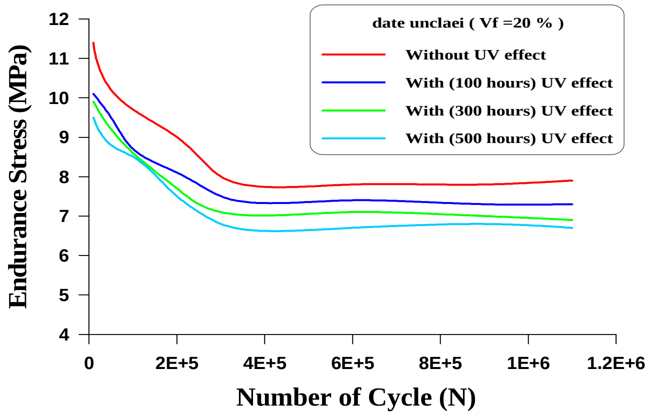

Figure 13: UV- Radiation Effect on Fatigue Test for Date Nuclei Composite Materials at 20% Volume Fraction

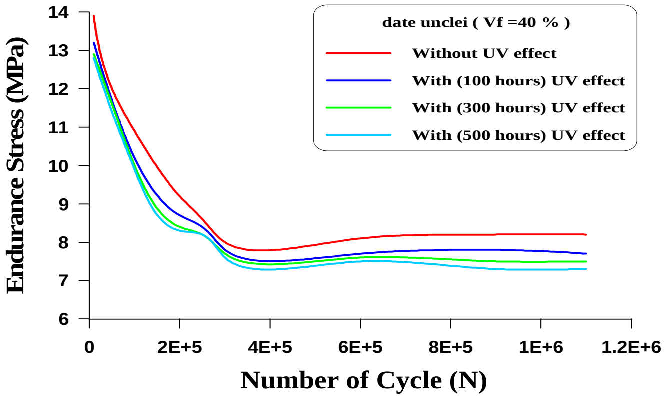

Figure 14: UV- Radiation Effect on Fatigue Test for Date Nuclei Composite Materials at 40% Volume Fraction

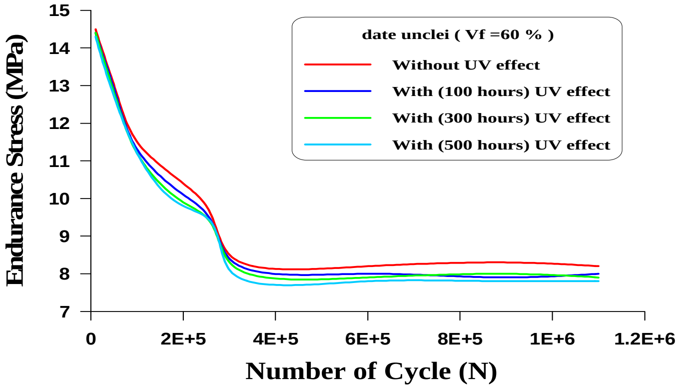

Figure 15: UV- Radiation Effect on Fatigue Test for Date Nuclei Composite Materials at 60% Volume Fraction

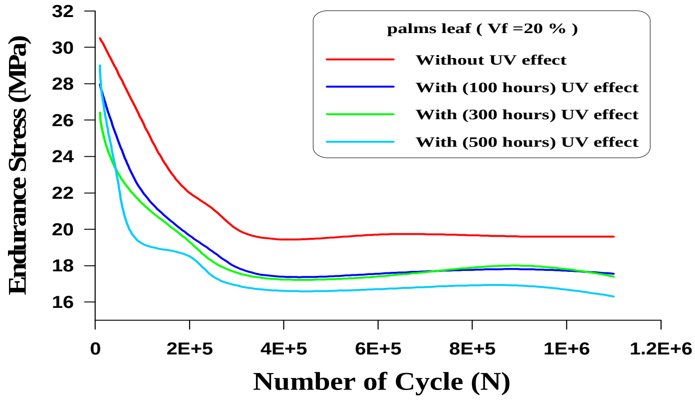

Figure 16: UV- Radiation Effect on Fatigue Test for Palm Leaf Composite Materials at 20% Volume Fraction

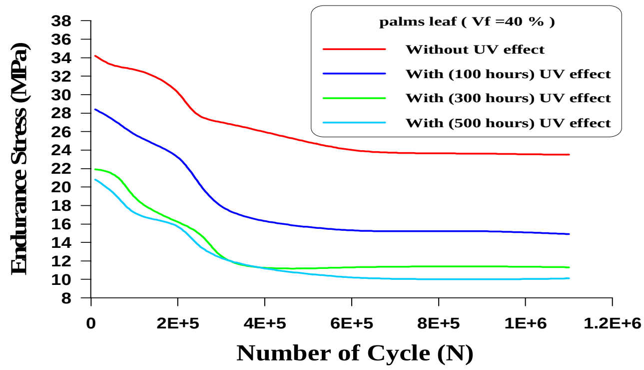

Figure 17: UV- Radiation Effect on Fatigue Test for Palm Leaf Composite Materials at 40% Volume Fraction

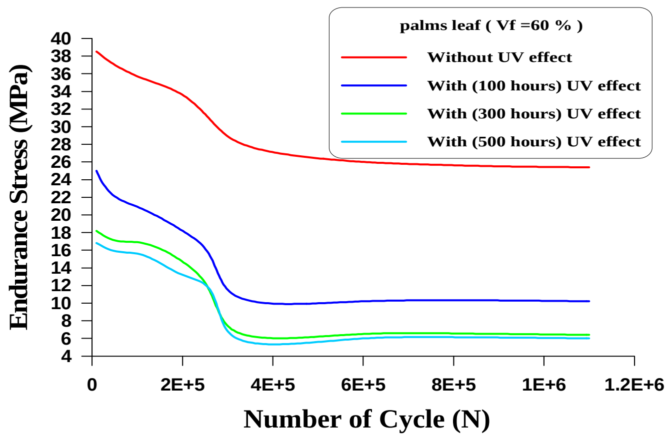

Figure 18: UV- Radiation Effect on Fatigue Test for Palm Leaf Composite Materials at 60% Volume Fraction

Table 3: Reduction of Endurance Stress for Natural Composite Material duo to UV-Radiation

Natural Composite Sample Type	Reduction of Endurance Stress %			
	Volume Faction %	UV-Radiation Time (100 hour)	UV-Radiation Time (300 hour)	UV-Radiation Time (500 hour)
Egg shell	20	4.37	10. 08	38.7
	40	21.6	30.9	37.2
	60	25.6	31	33
date nuclei	20	7.6	12.6	15.1
	40	6.1	8.5	10.9
	60	**2.4**	3.6	4.8
palms leaf	20	10.7	11.2	16.8
	40	36.6	51.9	57
	60	59.8	47.8	**76.3**

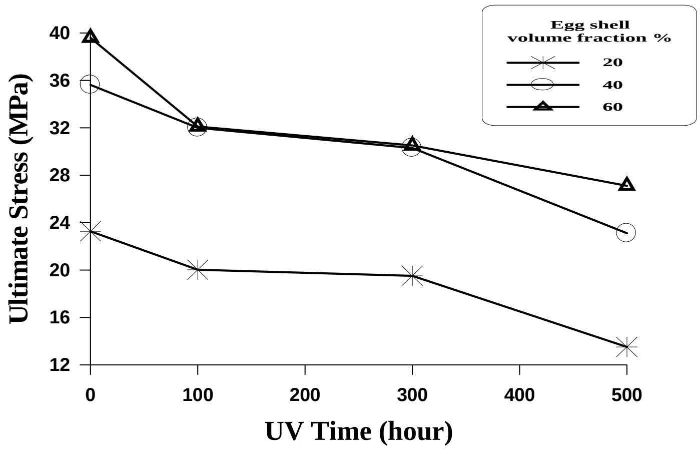

Figure 19: UV-Radiation Effect on Tensile Test for Egg Shell Composite Materials

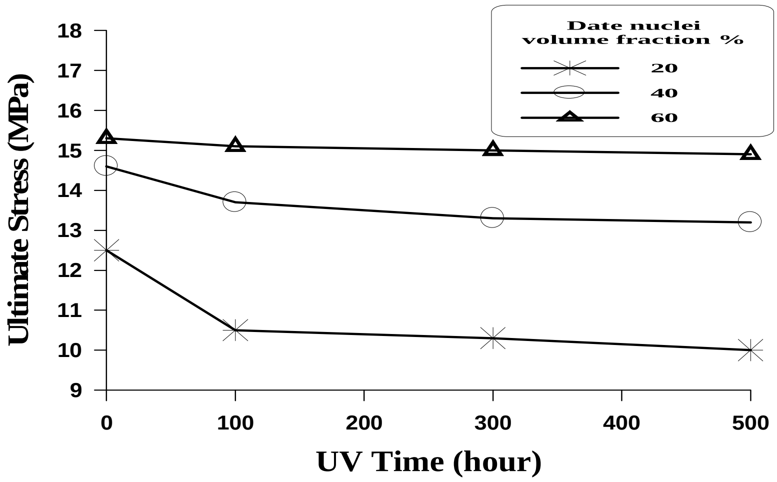

Figure 20: UV-Radiation Effect on Tensile Test for Date Nuclei Composite Materials

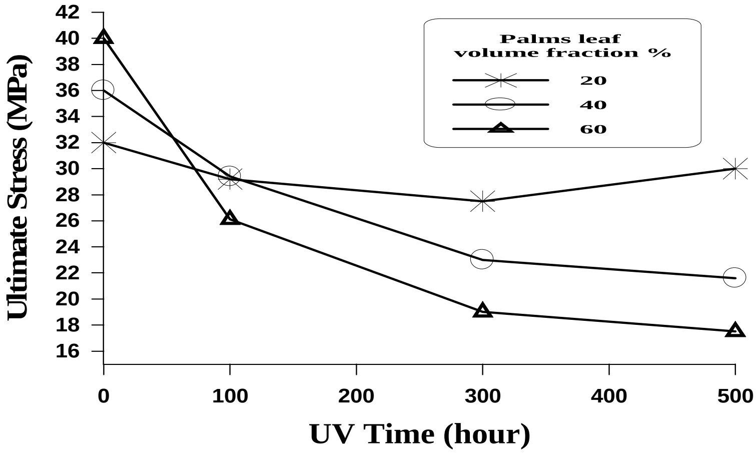

Figure 21: UV-Radiation Effect on Tensile Test for Palm Leaf Composite Materials

CONCLUSIONS

The main conclusions are

- The increasing volume fraction causes increasing of endurance stress of egg shell - polyester, date nuclei - polyester, and palm leaf – polyester natural composite materials.
- The palm leaf – polyester natural composite materials have mechanical properties better than egg shell - polyester, date nuclei – polyester composite materials.
- The increasing time of UV- radiation causes reduction in the endurance and tensile stresses of natural composite materials.
- The greatest reduction in the endurance stress duo to UV- radiation occur's for palm leaf natural composite material at 60 % volume fraction.
- The smallest reduction in endurance stress duo to UV- radiation occurs for date nuclei natural composite material at 60 % volume fraction. Therefore, the date nuclei natural composite material has good resistance to UV- radiation under fatigue effect.

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